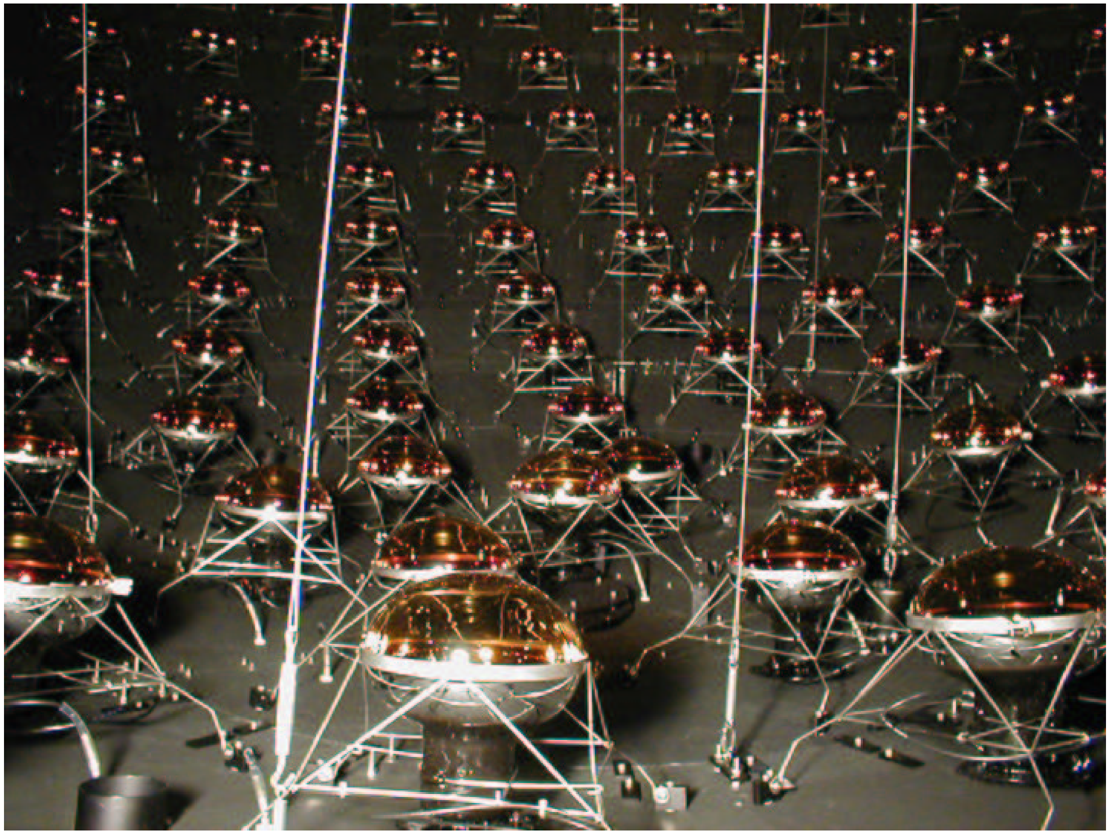
MiniBooNE Status



Ryan B. Patterson
Princeton University

Argonne Workshop on Trends in Neutrino Physics, Argonne National Laboratry
May 14, 2003

The collaboration

~60 scientists

13 institutions

University of Alabama

Bucknell University

University of California, Riverside

University of Cincinnati

University of Colorado

Columbia University

Embry Riddle Aeronautical University

Fermi National Accelerator Laboratory

Indiana University

Los Alamos National Laboratory

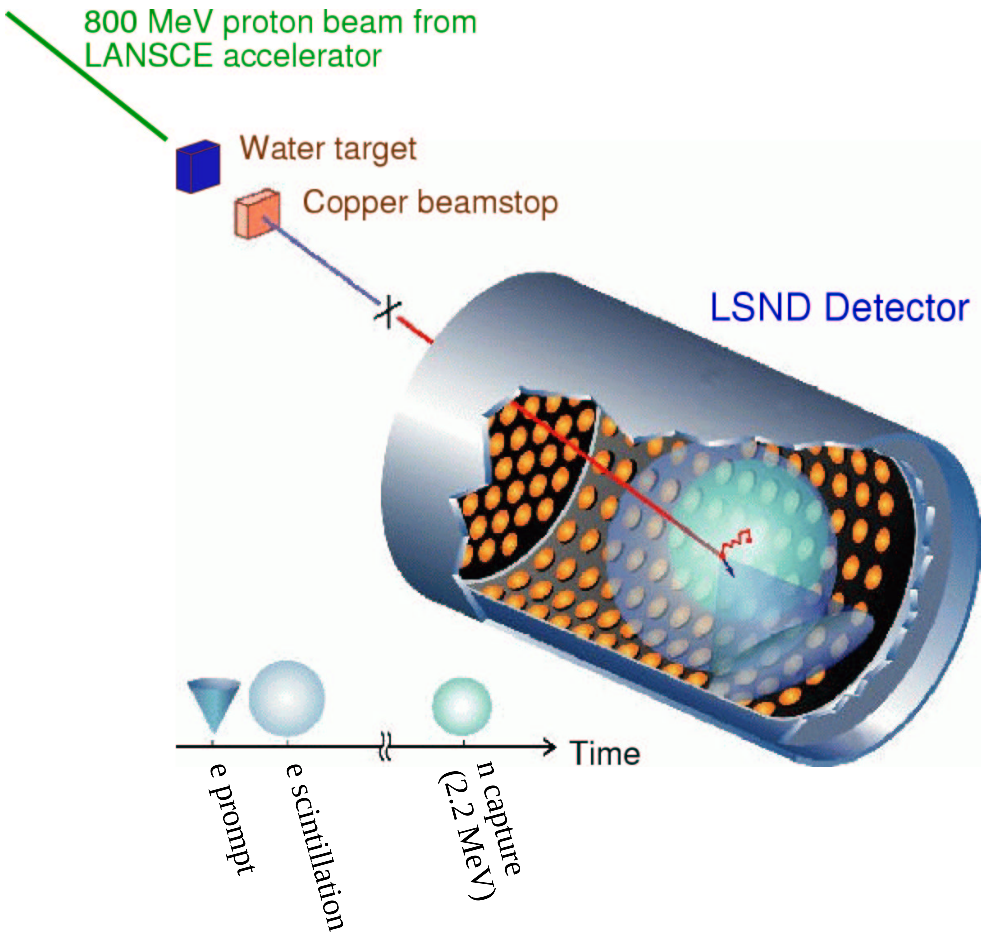
Louisiana State University

University of Michigan

Princeton University

Investigating the LSND result

LSND:



- searched for $\bar{\nu}_e$ in $\bar{\nu}_\mu$ beam
- 3.8σ excess over background

$\bar{\nu}_e$ events over background:

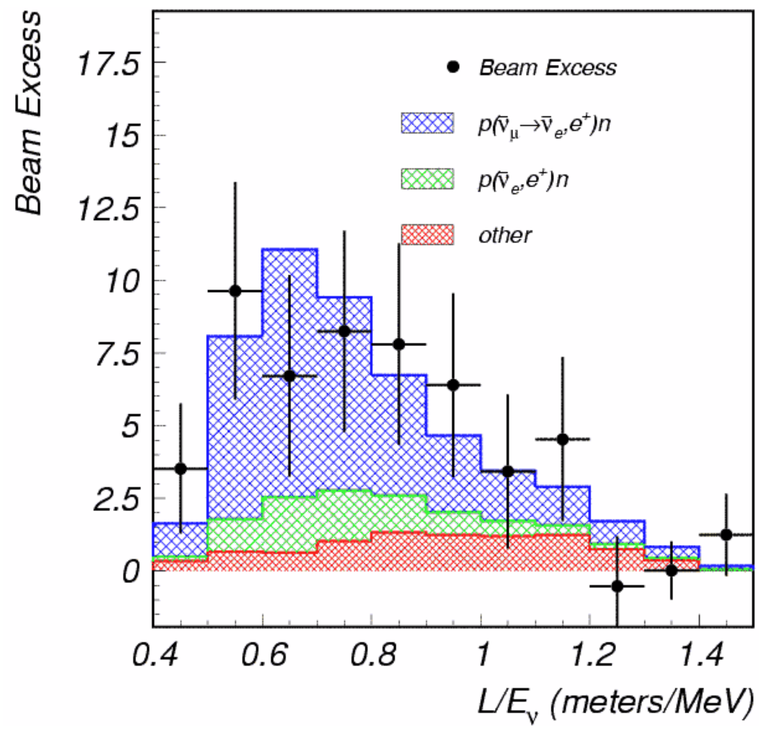
$87.9 \pm 22.4 \pm 6.0$

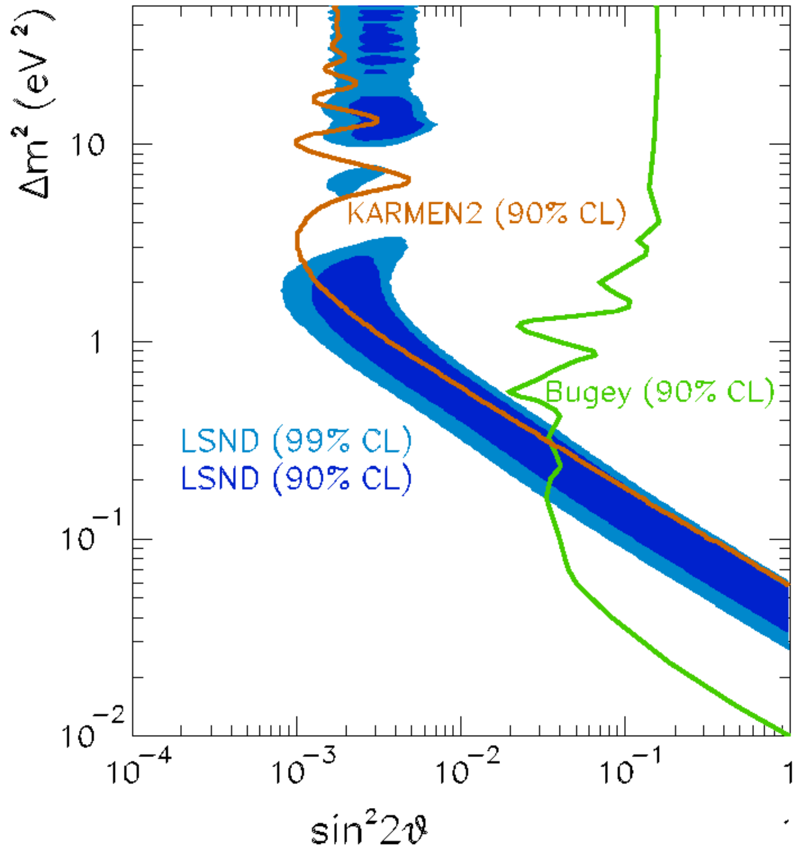
oscillation probability:

$(0.264 \pm 0.067 \pm 0.045)\%$

Phys. Rev. D **64**, 112007 (2001)

The LSND result:





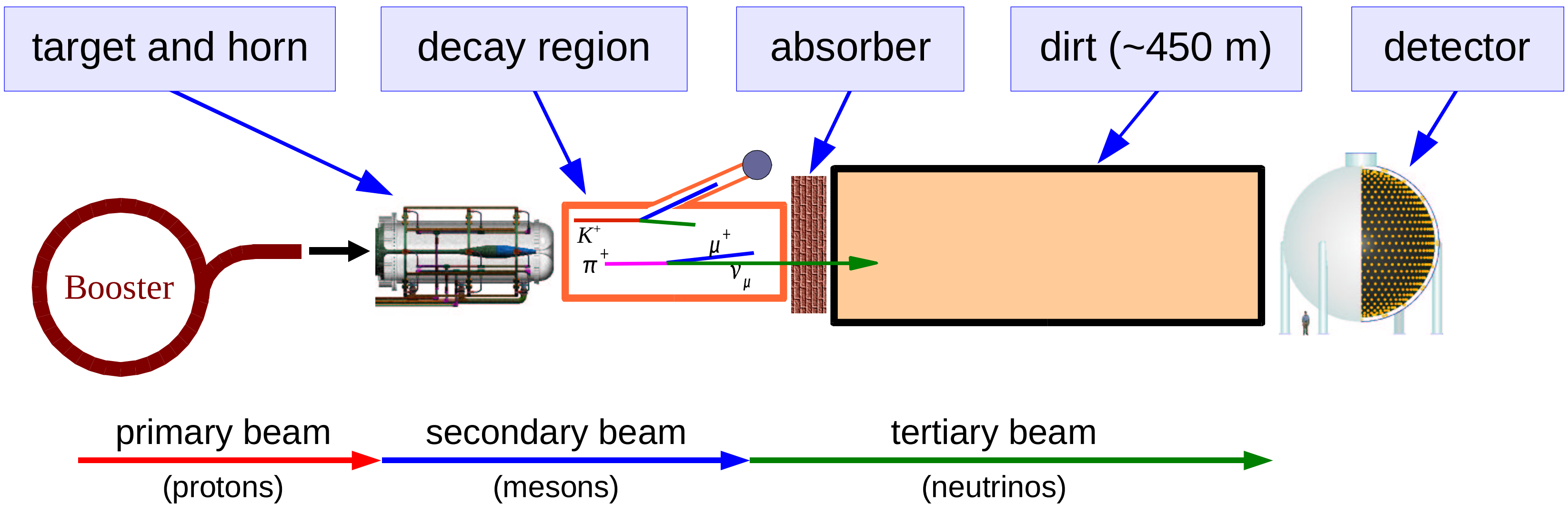
- taking atmospheric, solar, reactor, and LSND results together...
  - one or more experiments is not seeing oscillations, *or*
  - there are more than 3 neutrinos, *or*
  - CPT is not a good symmetry, *or*
  - ?

G. Barenboim, L. Borissov, and J. Lykken, hep-ph/0212116

To check LSND, you want...

- similar L/E_ν
- different systematics
- higher statistics

MiniBooNE



primary beam

- 8 GeV protons from FNAL Booster
- through MiniBooNE beamline

secondary beam

- mesons produced at beryllium target
- magnetic horn focuses these down 50 m decay pipe

tertiary beam

- neutrinos from meson decay
- 450 m path through dirt to detector

$$\nu_\mu \rightarrow \nu_e \quad \text{search}$$

$$L_{\text{MiniBooNE}} \sim 10\, L_{\text{LSND}}$$

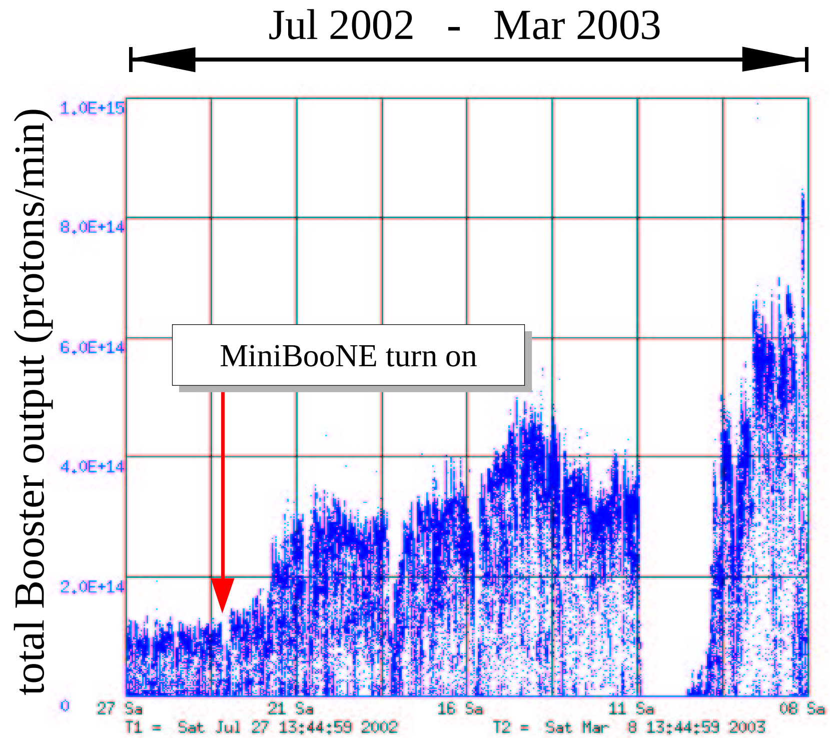
$$E_{\text{MiniBooNE}} \sim 10\, E_{\text{LSND}}$$

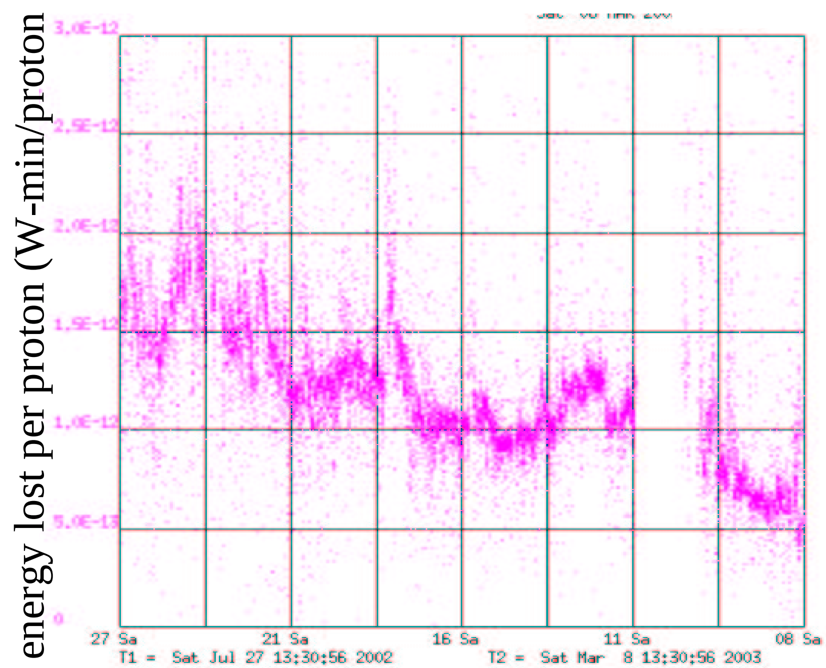
- different signal
- different backgrounds

$\Rightarrow$ *different systematics*

Booster performance

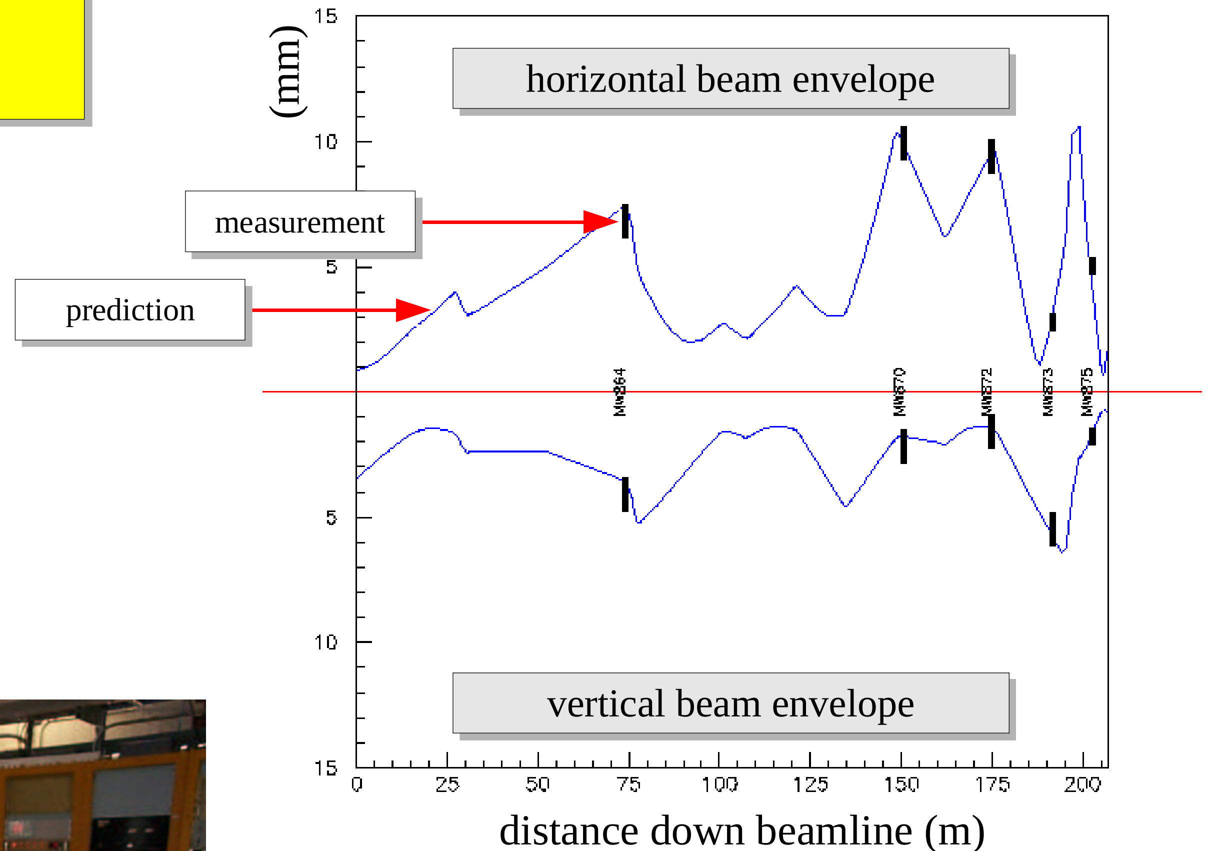
- Booster has never worked this hard
- steady increase
  - careful tuning
  - optimizing pulse rate / pulse intensity
  - hardware changes
- need factor of ~2-3 to reach total of 10^{21} protons on target
- further improvements coming
  - collimator project (underway)
  - large-aperture RF cavities





Beamline and horn

- 8 GeV MiniBooNE transport line
  - first beam in final configuration: Aug 24, 2002
  - optics understood very well



- Horn
  - increases neutrino flux ~7x
  - 170 kA , 143 μs pulses @ 5 Hz
  - has performed flawlessly, with >20M pulses *in situ*

Intrinsic ν_e in the beam

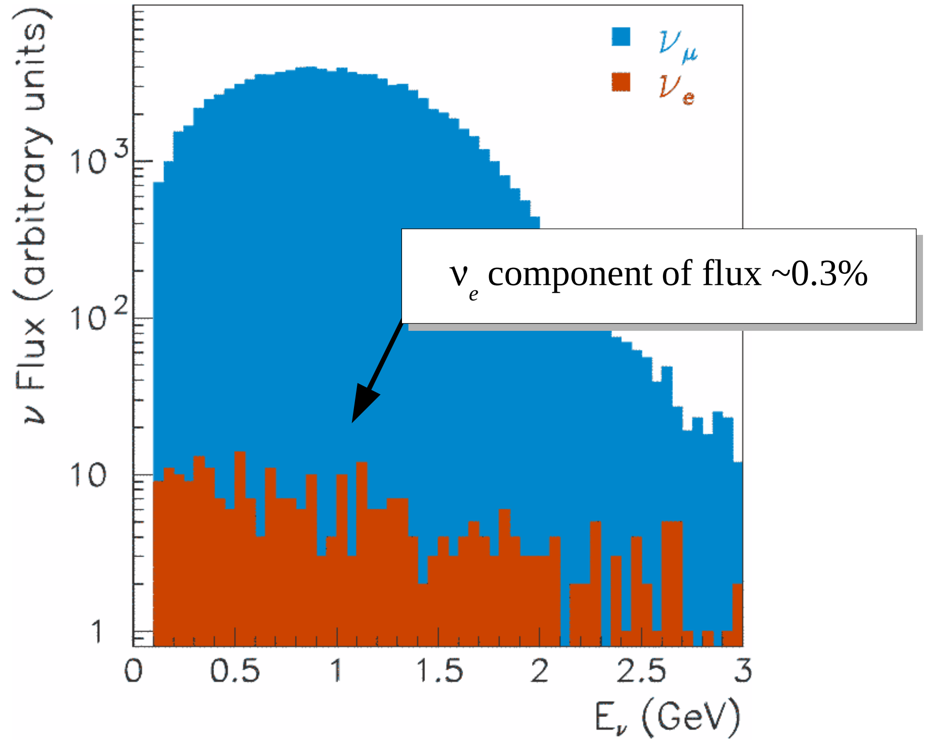
- a major background for the appearance experiment

- sources:

$$\pi^+ \;/\; K^+ \rightarrow \mu^+ \, \nu_\mu$$
$$\hookrightarrow e^+ \, \bar{\nu}_\mu \, \nu_e$$

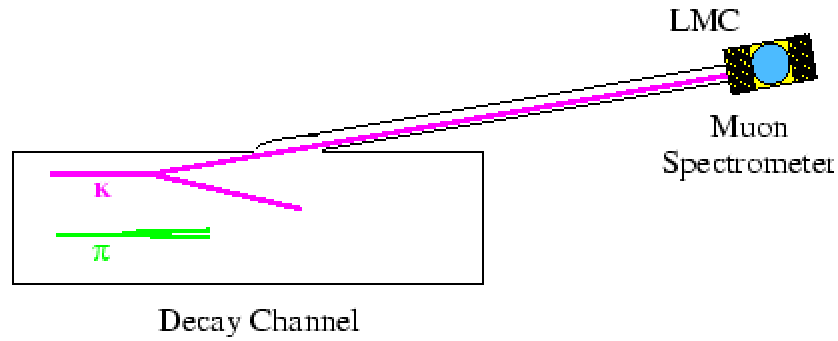
$$K^+ \;/\; K^0_L \rightarrow \pi \, e \, \nu_e$$

- tackle this background with
  - half-million ν_μ interactions in the detector
  - HARP experiment (CERN)
  - E910 (Brookhaven)
  - “little muon counter”
  - 25 m / 50 m decay length option



HARP experiment at CERN

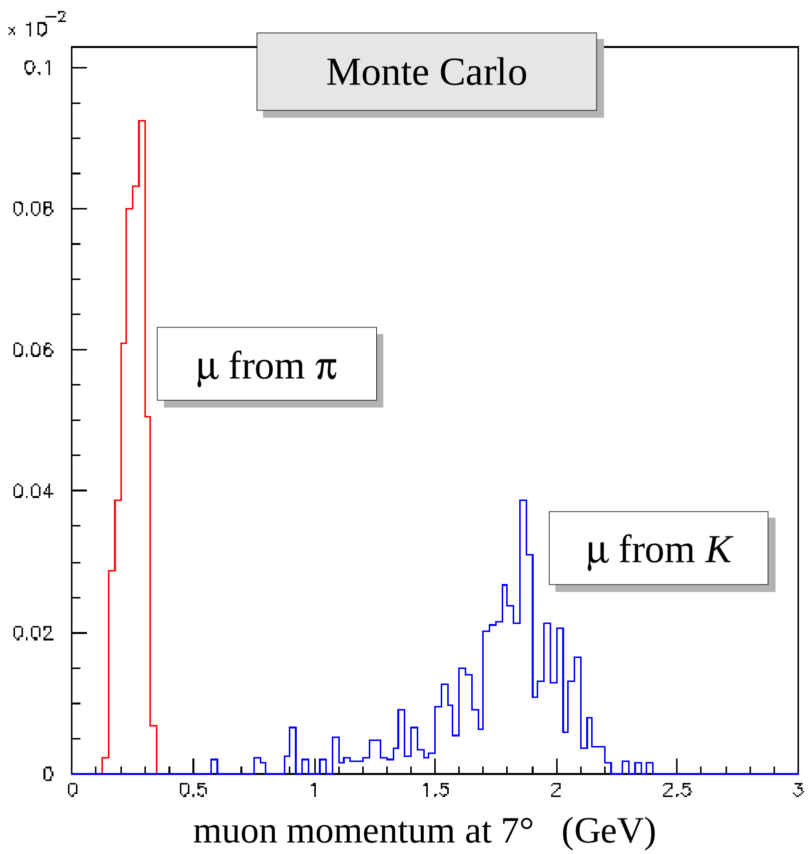
Little muon counter

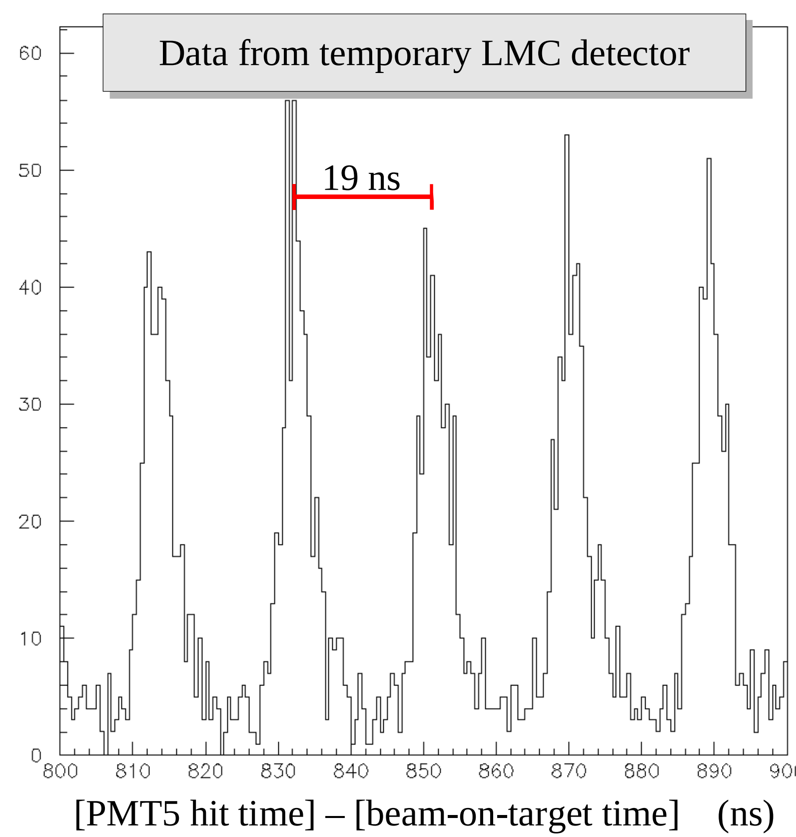


- *K* decays produce more wide-angle muons than π decays
- LMC: off-axis (7°) muon spectrometer
- scintillator fiber tracker
- clean separation of muon parentage

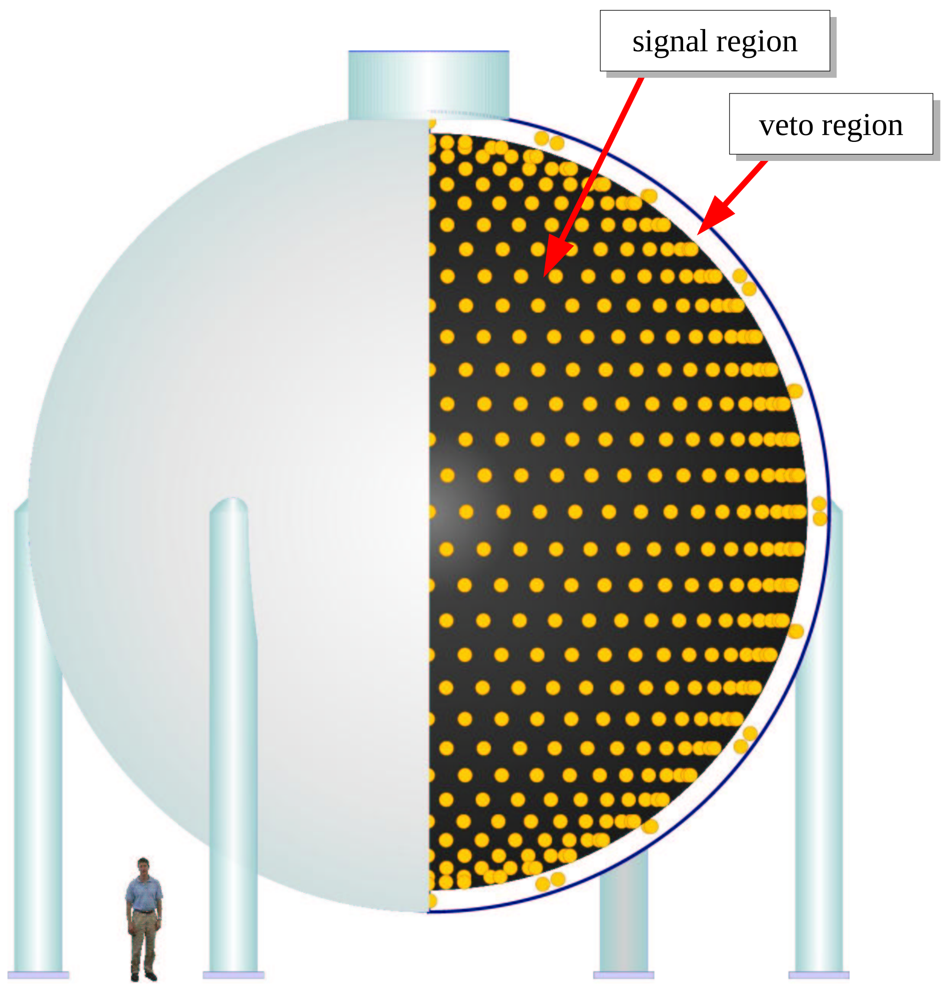
➔ temporary LMC detector (scintillator paddles):

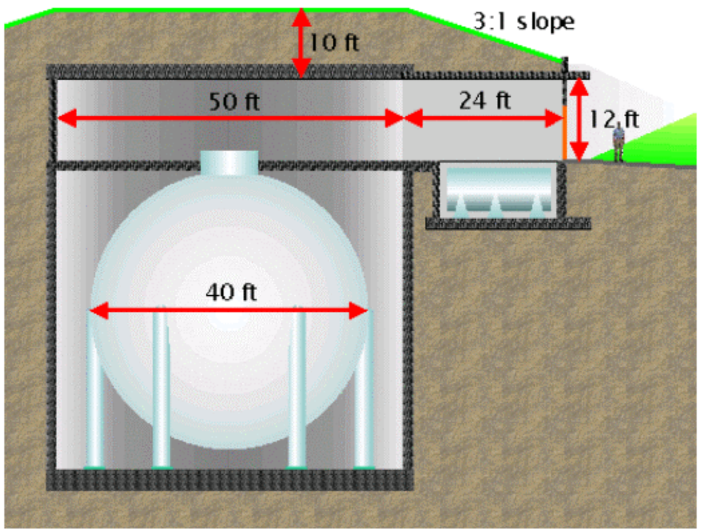
- shows that data acquisition is working
- 53 MHz beam RF structure seen





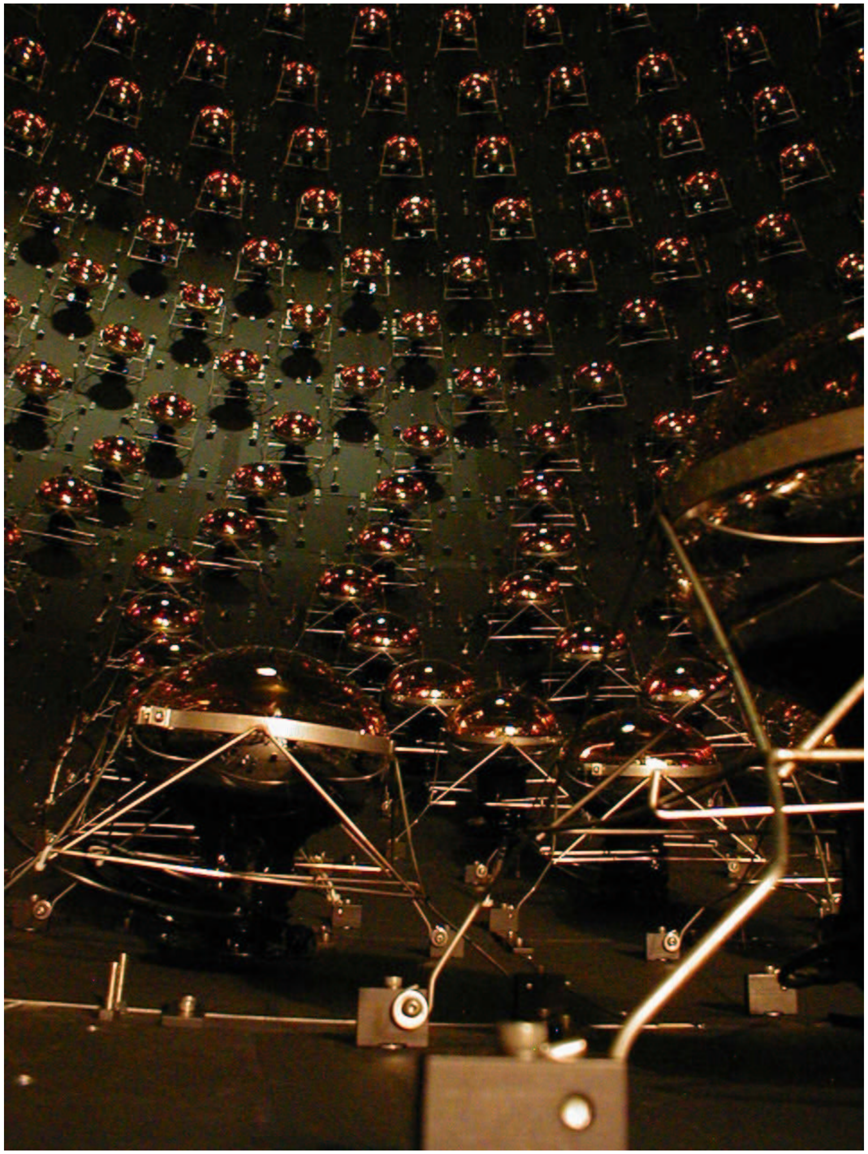
The MiniBooNE detector

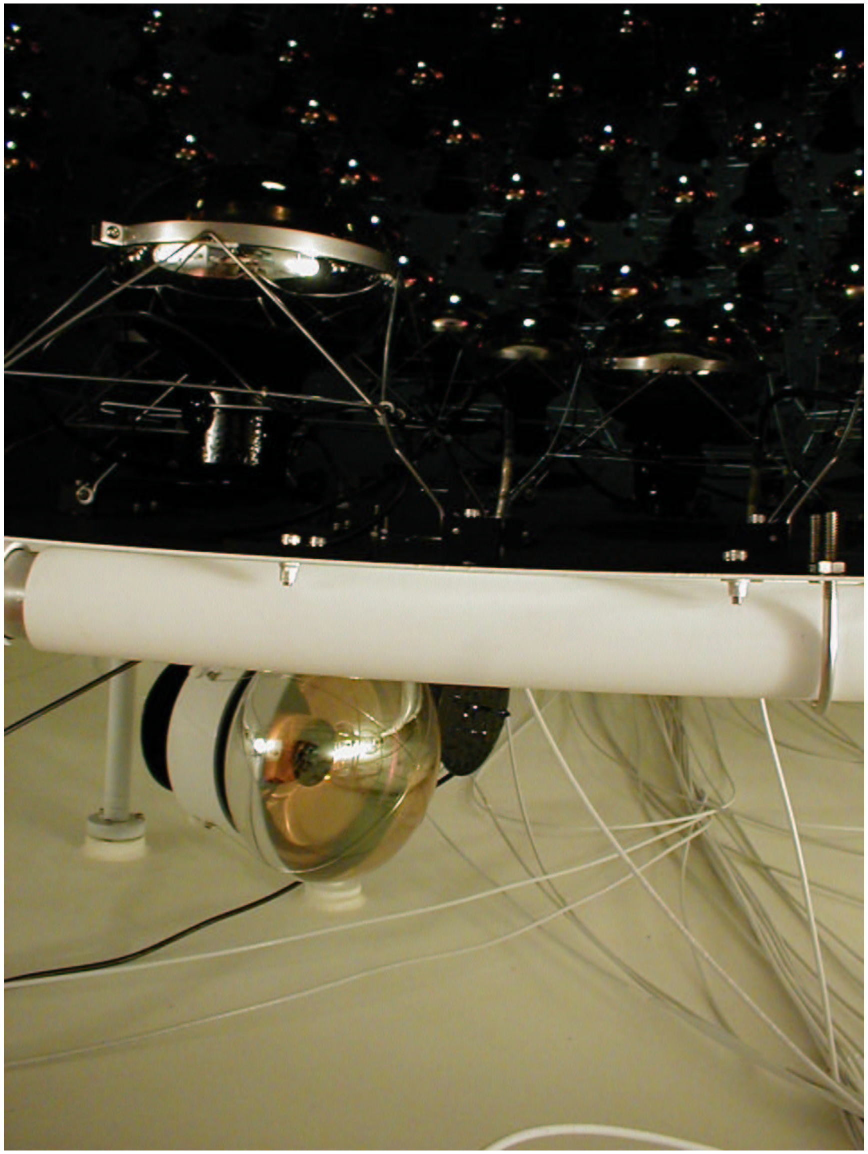




- 40 ft diameter sphere
- 800 tons of mineral oil
- 1280 8-inch phototubes in signal region (10% coverage)
- 240 8-inch phototubes in veto region

some views...



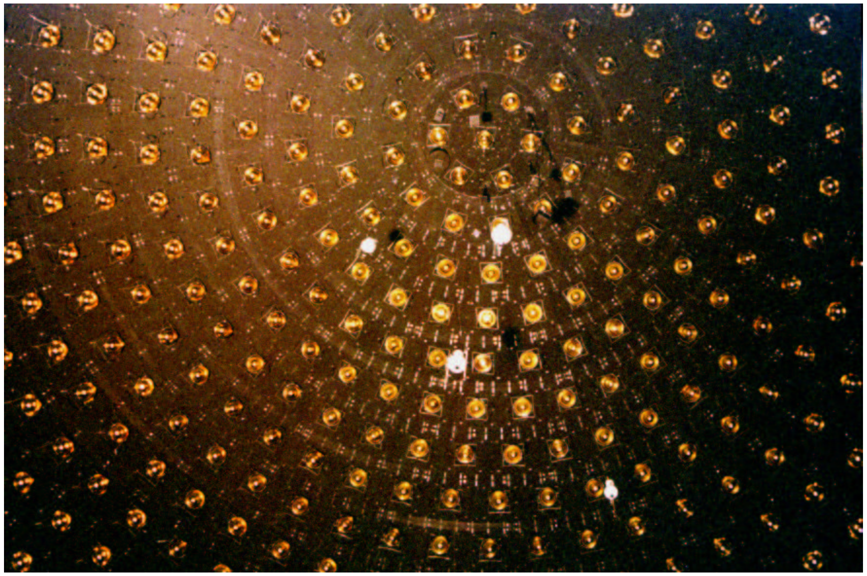


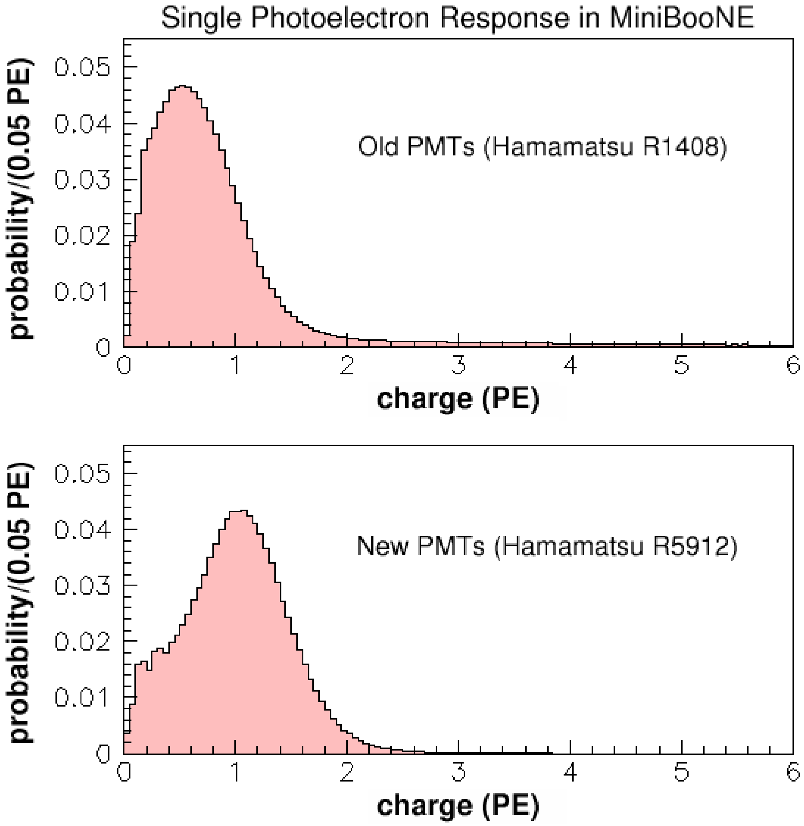
Understanding the detector

Laser flasks

- Ludox®-filled round flasks
- fed by optical fiber from laser
- four flasks distributed about detector

- ➔ attenuation length measurements
- ➔ charge response of phototubes

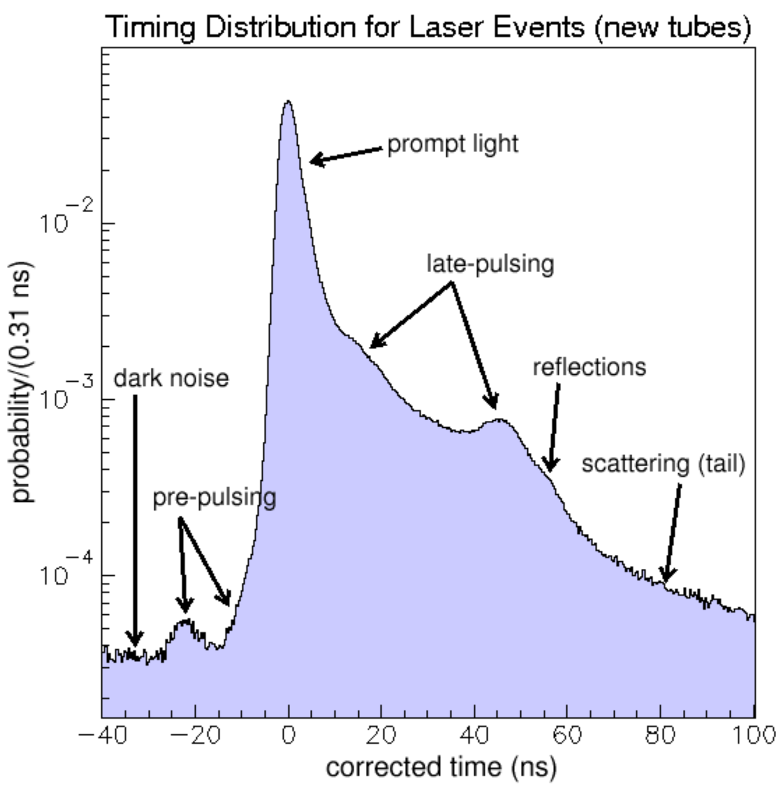


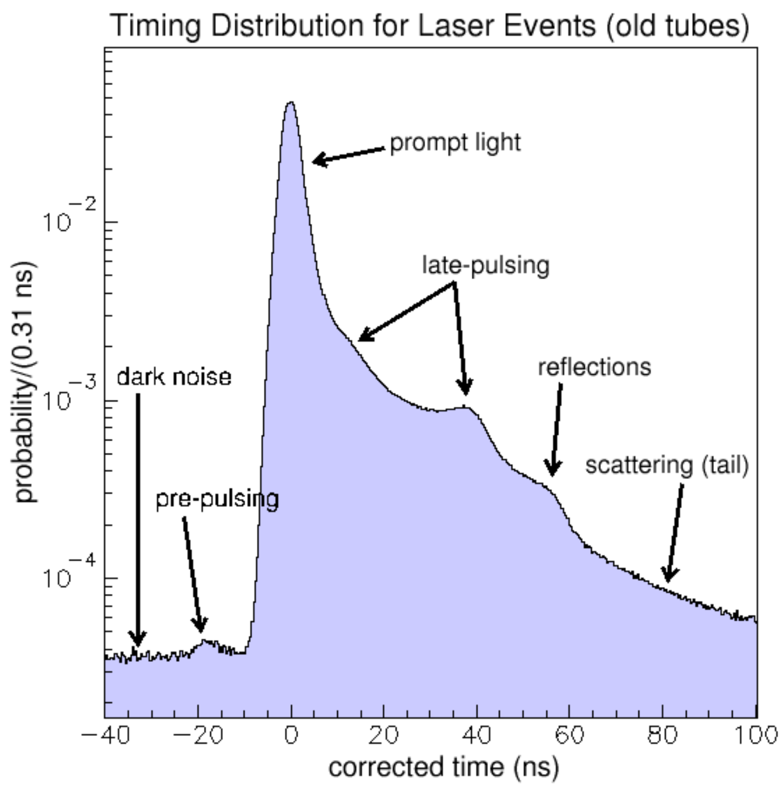


Laser flasks (cont'd)

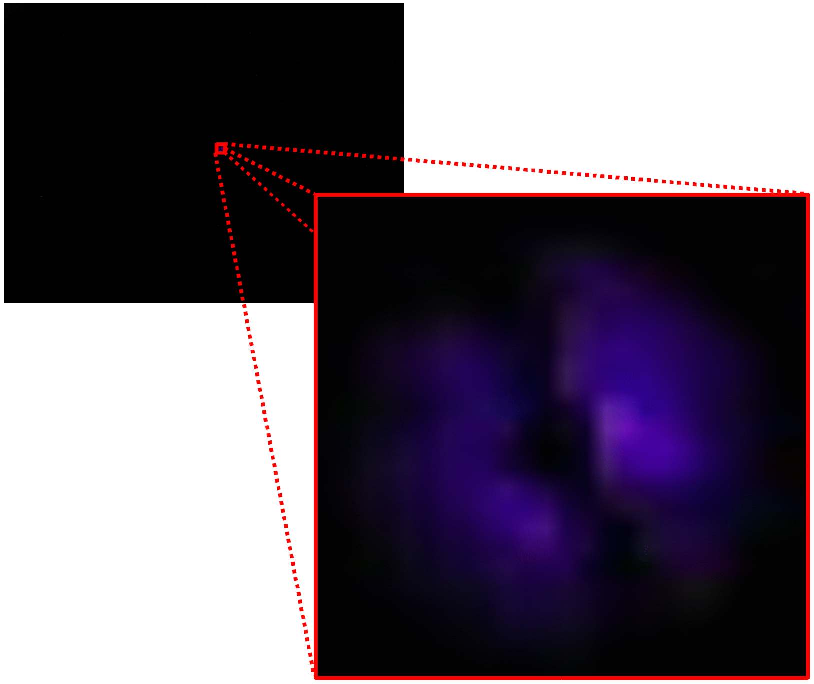
- time response of tubes (resolution, slewing, etc.)
  - time resolutions from data: 1.2 ns (new tubes), 1.7 ns (old tubes)
  - in agreement with benchtop measurements / tube specifications
  - important for reconstruction and particle ID

- global properties of detector/phototube time response:





view from bottom of detector:
lights out, flask on



Laser flasks (cont'd)

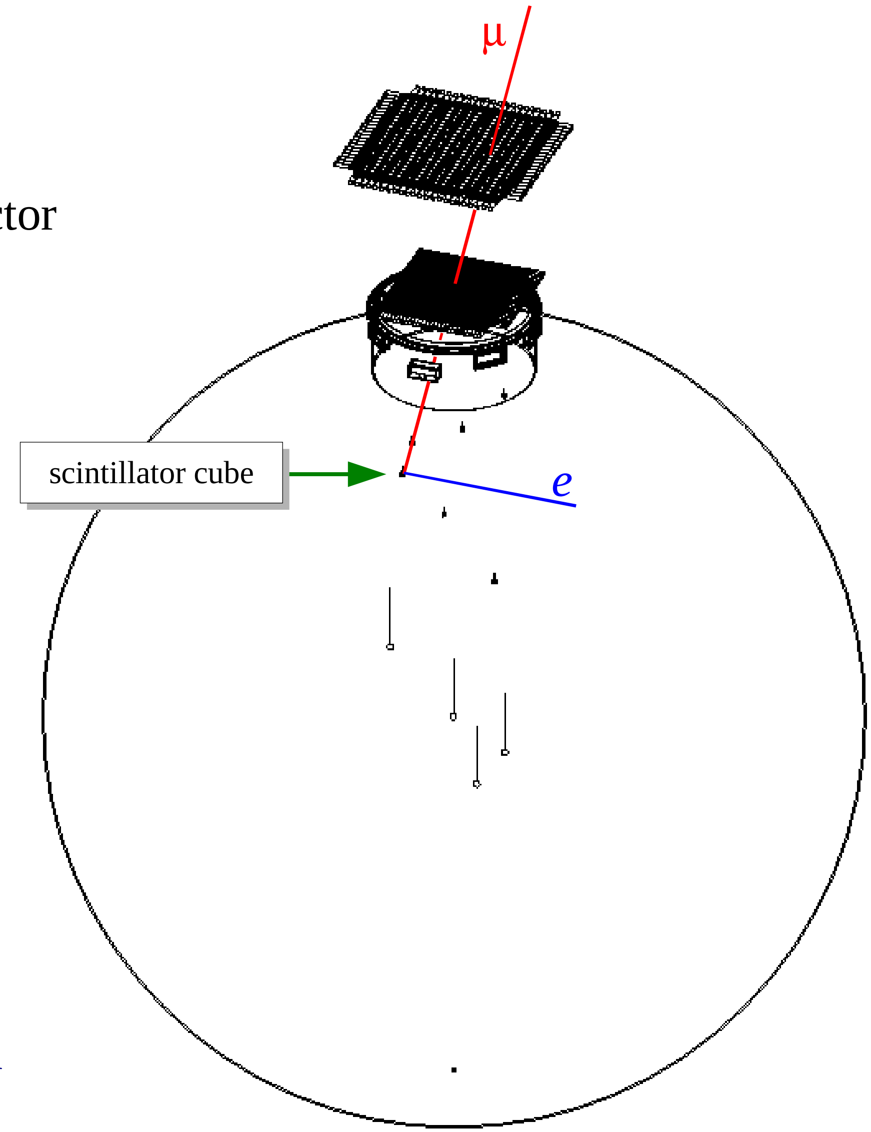
- also use to understand
  - high-charge effects
  - vertex reconstruction resolution, biases

Muon tracker system

- four planes of scintillator strips
- provides muons of known direction
- key to understanding event reconstruction

Muon tracker plus scintillator cubes

- seven enclosed cubes of scintillator in detector volume
- tracker/cube combination provides
  - muons with known pathlength
  - electrons with known vertex

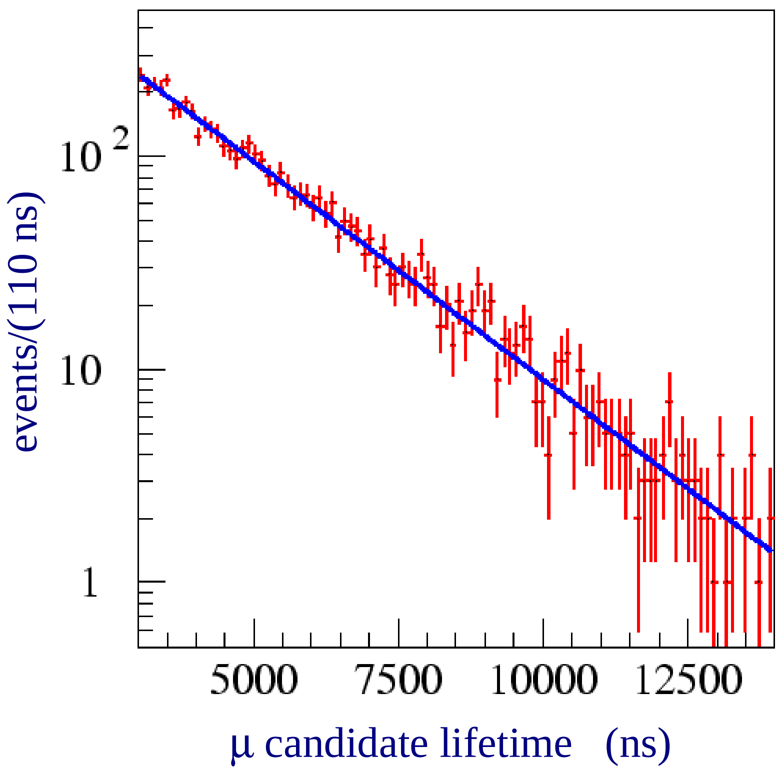


Michel electrons throughout detector

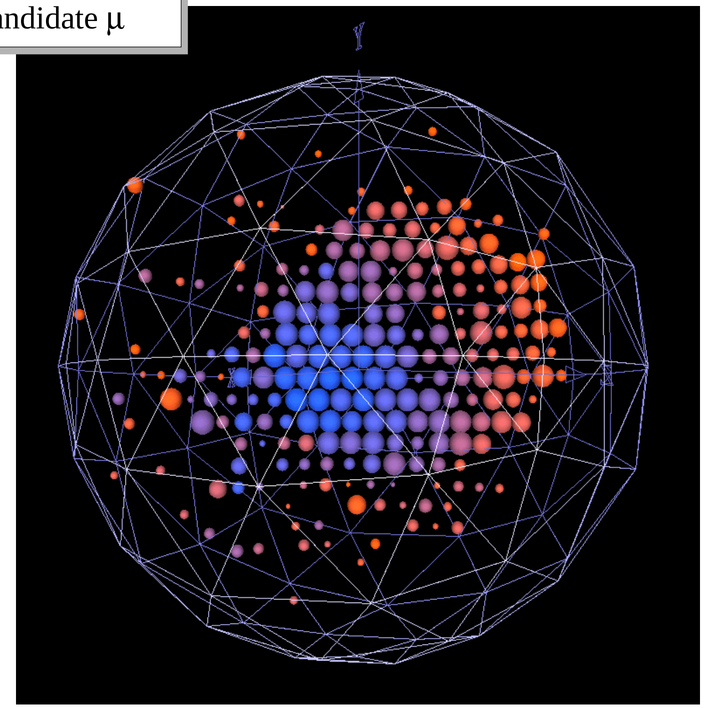
- plentiful source from cosmics and beam-induced muons
  - get energy scale and resolution at Michel endpoint
  - beam-on v. beam-off calibration check
  - electron particle ID

Michel electrons (cont'd)

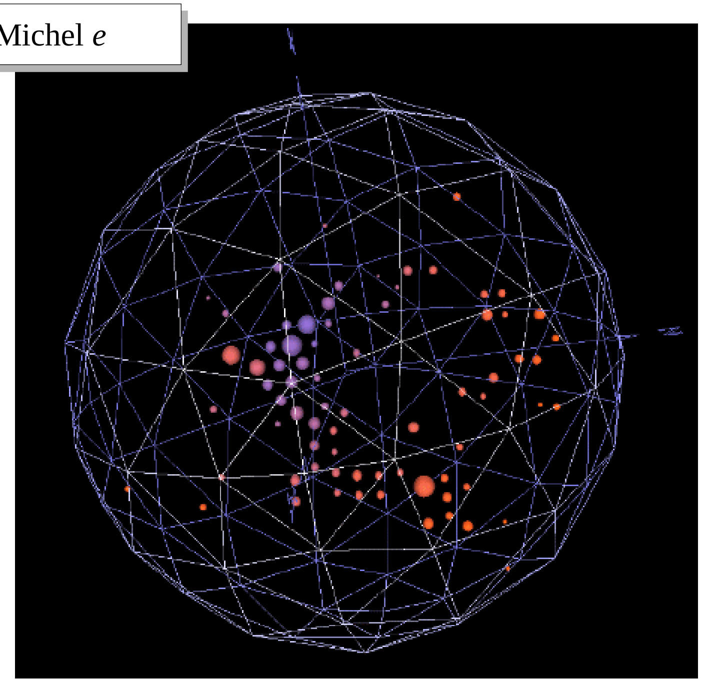
- candidate muon and subsequent Michel electron →
- cosmic muon lifetime in oil
  - measured: $\tau = 2.12 \pm 0.05$ μs
  - expected: $\tau = 2.13$ μs (8% μ^- capture)



candidate μ



Michel *e*



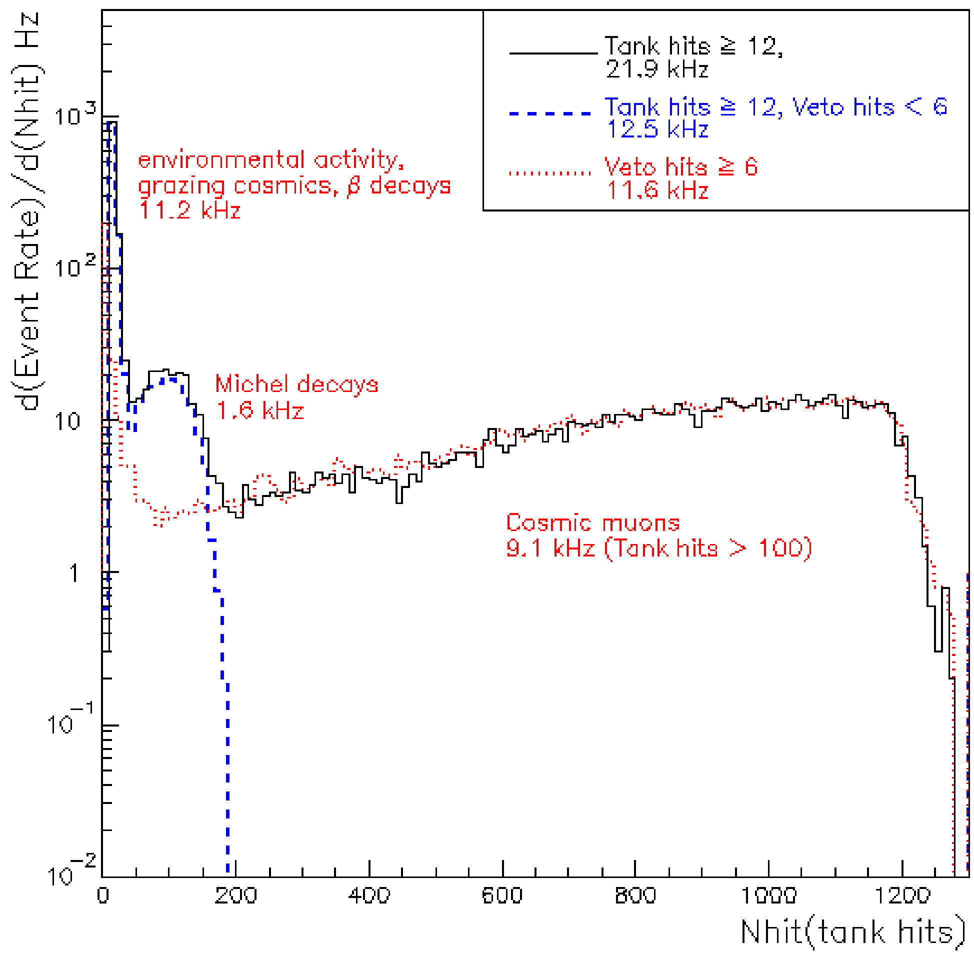
color=time size=charge

The MiniBooNE trigger

- typical MiniBooNE tank DAQ triggers
  - beam 3 Hz (currently)
  - random 2 Hz
  - laser flasks 1 Hz
  - tank/veto NHIT 1 Hz
  - Michel 1 Hz
  - tracker/cubes 1 Hz
  - gamma/beta 1 Hz
  - supernova 11 Hz

  total: ~22 Hz

- headroom available for bursts
- understand detector response down to a few MeV
- high veto efficiency



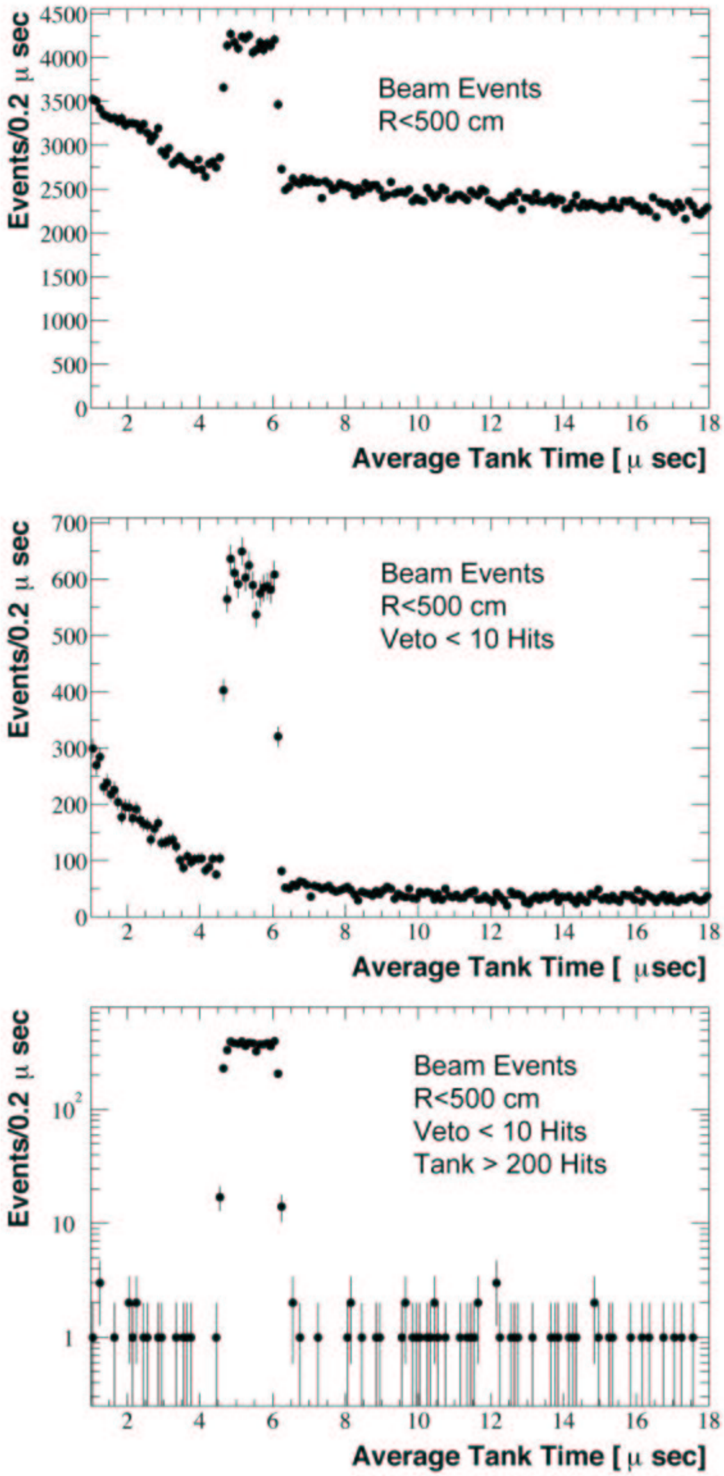
Coarse beam timing

- beam comes in spills @ 5 Hz
- each spill: ~82 buckets separated by 19 ns

  $\Rightarrow$ ~1.6 μs spill

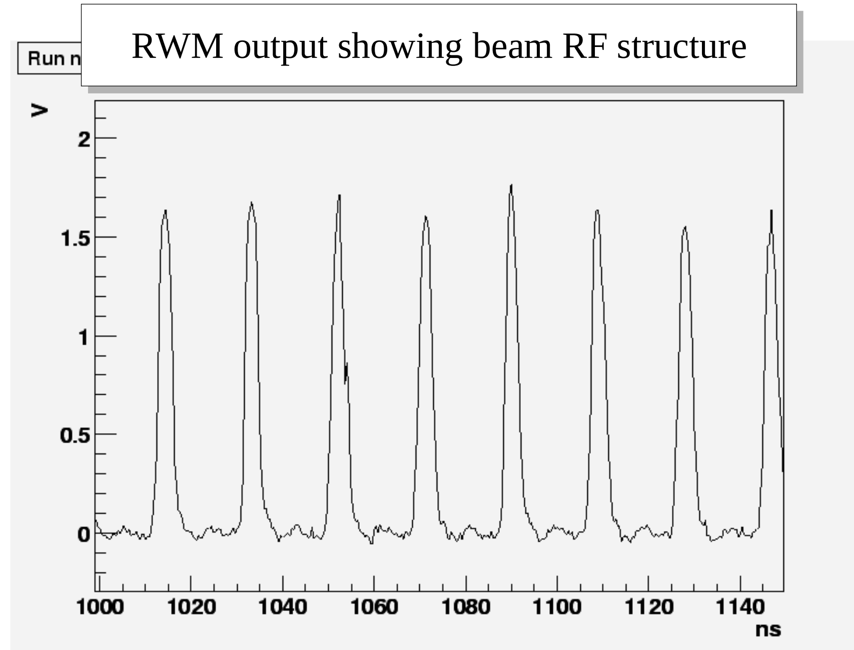
- trigger on signal from Booster; read out for 19.2 μs
- no high level analysis needed to see neutrino events over background!
- and...

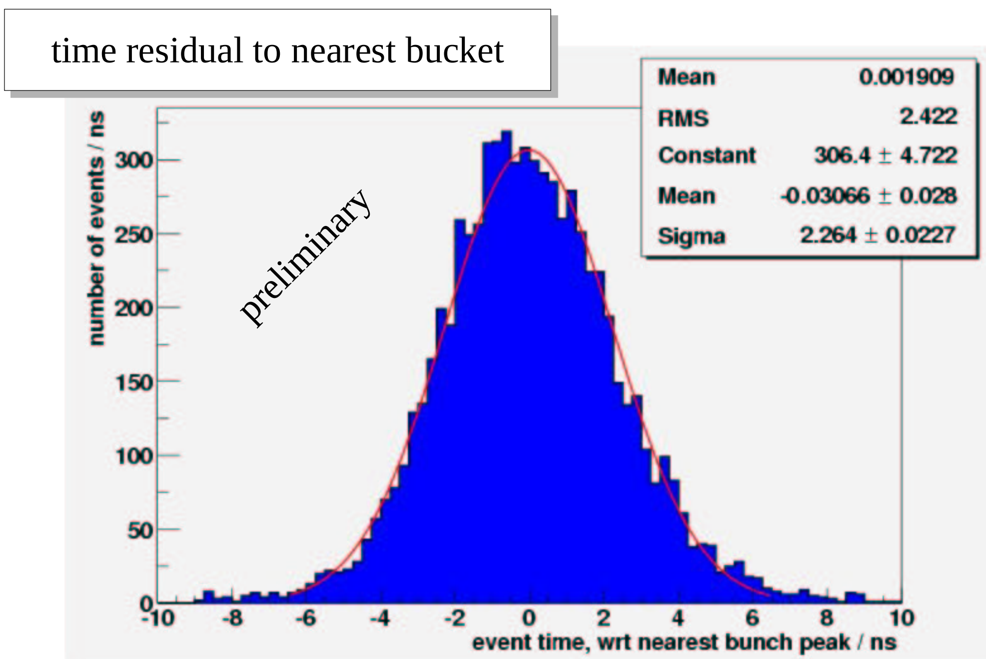
Adding a few simple cuts reduces the non-beam background to ~10^{-3}.



Fine beam timing

- resistive wall monitor (RWM) near target
- RWM signal discriminated, sent to detector DAQ
- with reconstructed neutrino event, can
  - determine event time (from start of spill)
  - adjust for vertex
  - find time to nearest RF bucket

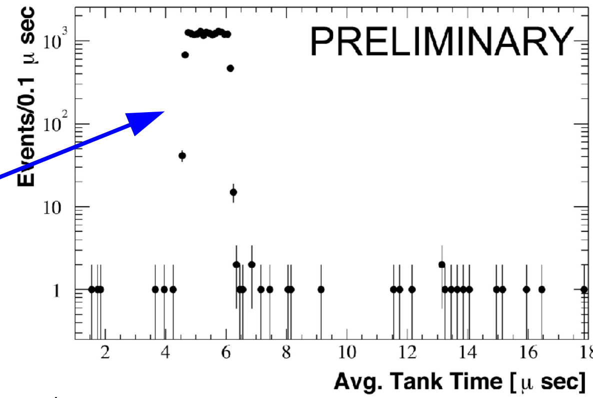




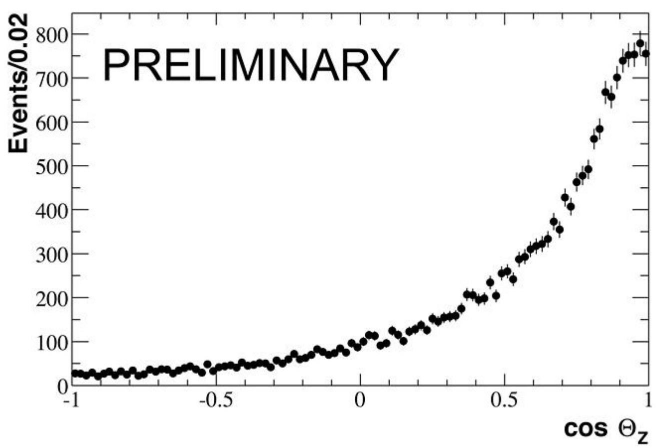
We can measure the Booster bucket structure with neutrinos in the detector.

Neutrino events

- look at these events

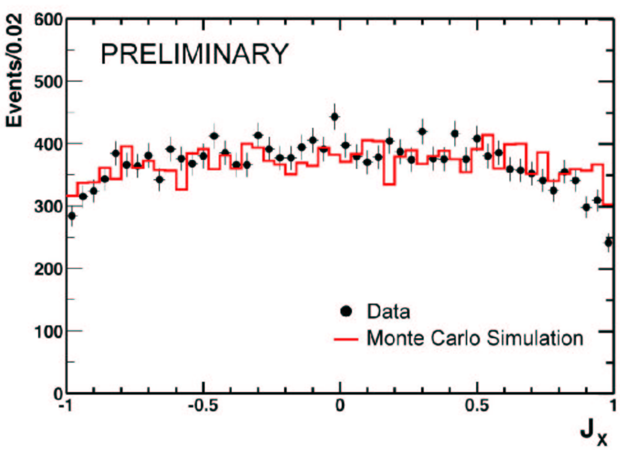


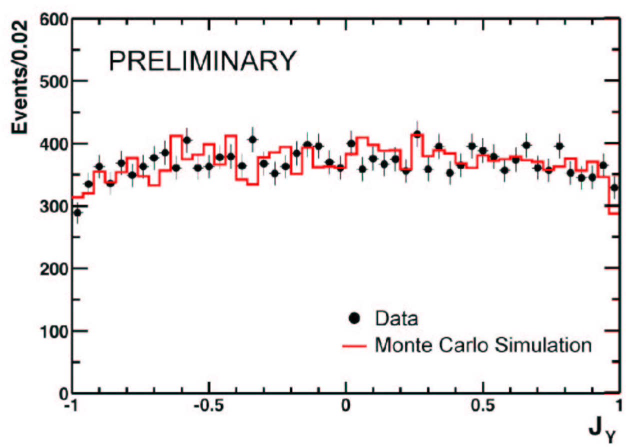
- track direction ⇒ these are beam events:

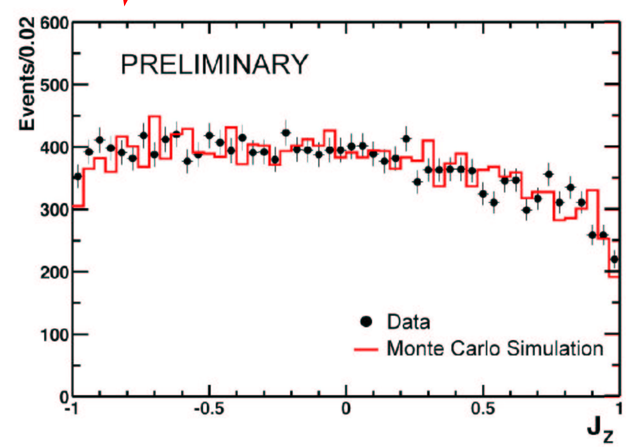


reconstructed track direction
w.r.t. neutrino beam direction

event vertex (in “reduced” coordinates)







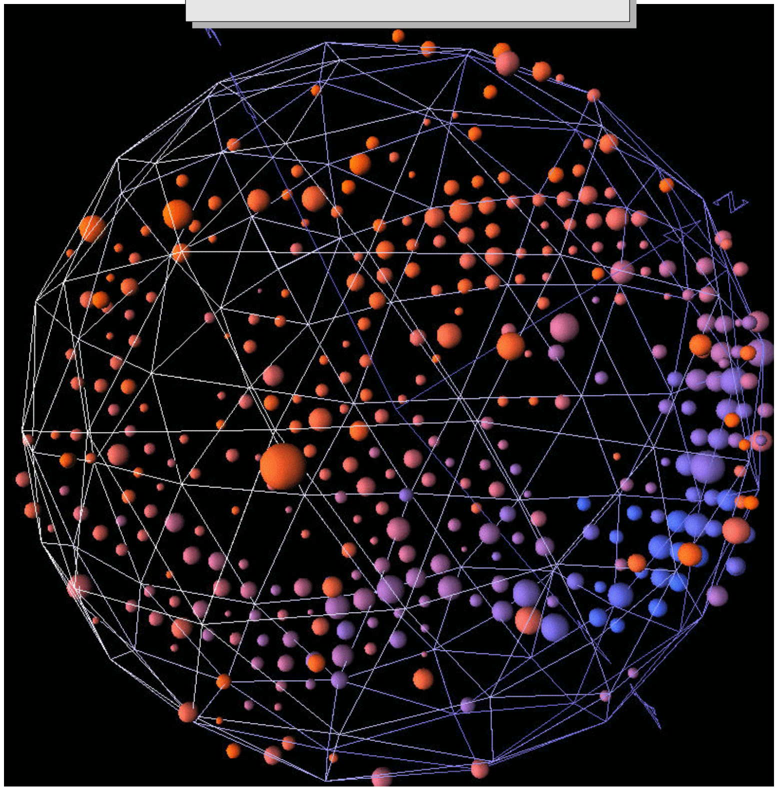
π^0 background

$\nu_\mu C \to \nu_\mu X \pi^0$

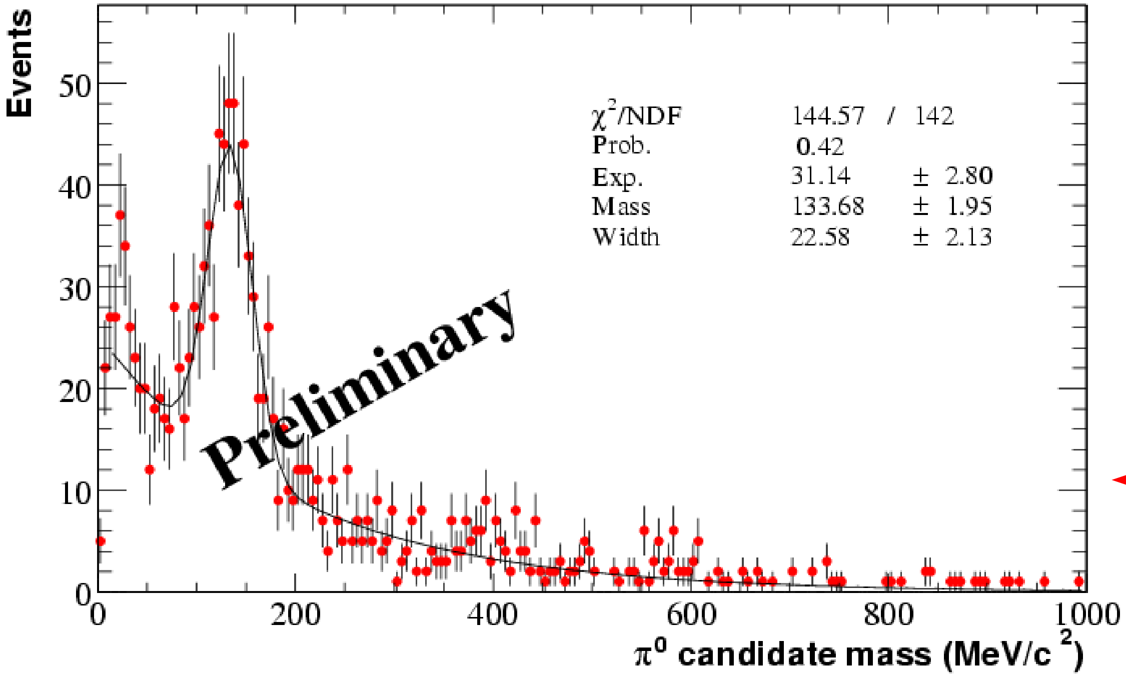
- $\pi^0 \to \gamma\gamma$ can mimic an e^-
  - escaping γ
  - "asymmetric" decays
  - ring overlap

- π^0 events are useful calibration sources

π^0 candidate event



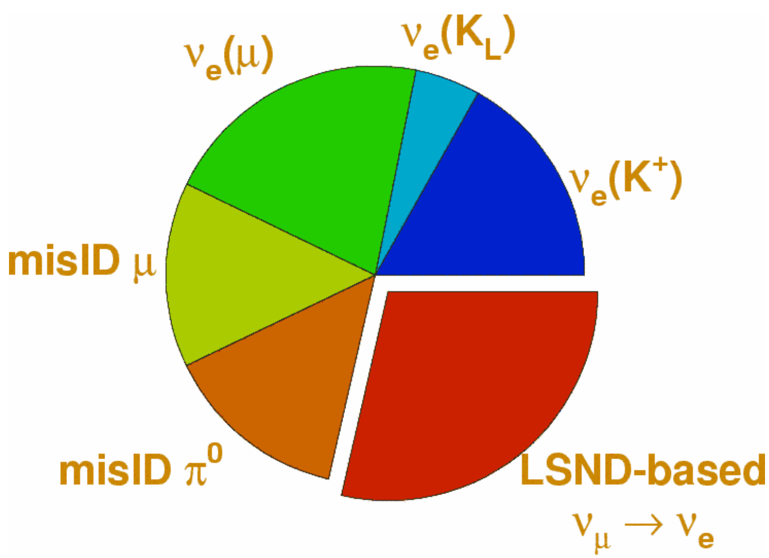
- high-energy electron-like tracks (can check electron reconstruction)



the π^0 peak stands out with minimal cuts

Returning to oscillations

backgrounds and signal (preliminary estimates)

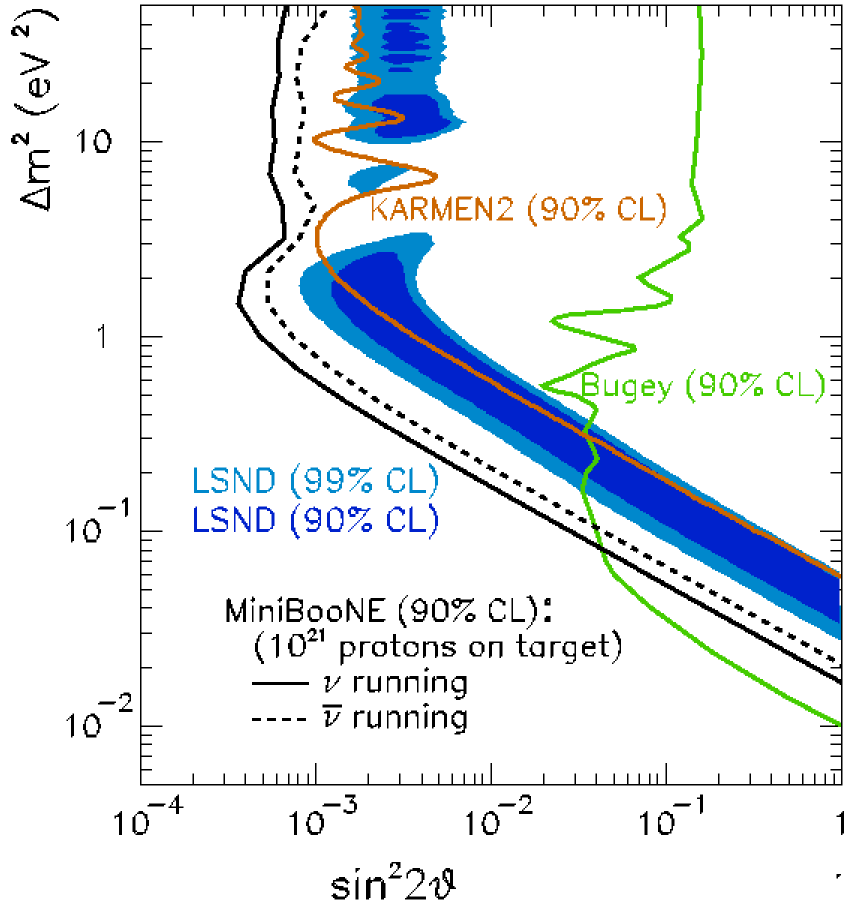



1,500 intrinsic ν_e


500 μ mis-ID


500 π^0 mis-ID


1,000 LSND-based $\nu_\mu \rightarrow \nu_e$ signal



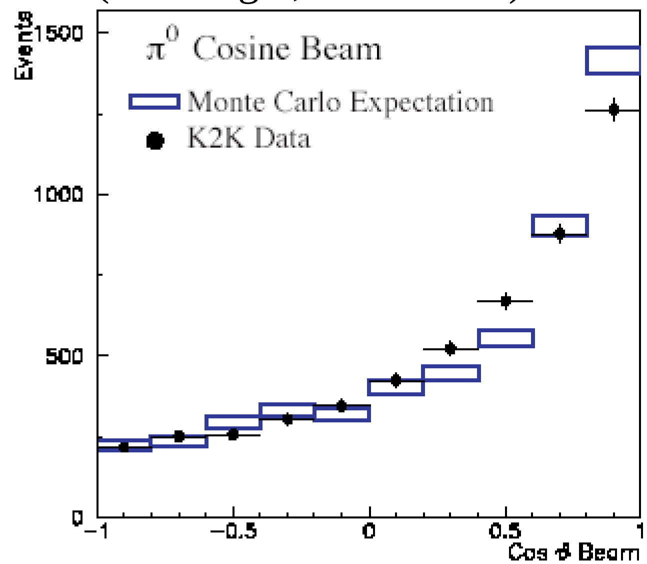
- cover entire LSND allowed region at >5σ
- updated estimates coming
- currently expect results in 2005

Other physics

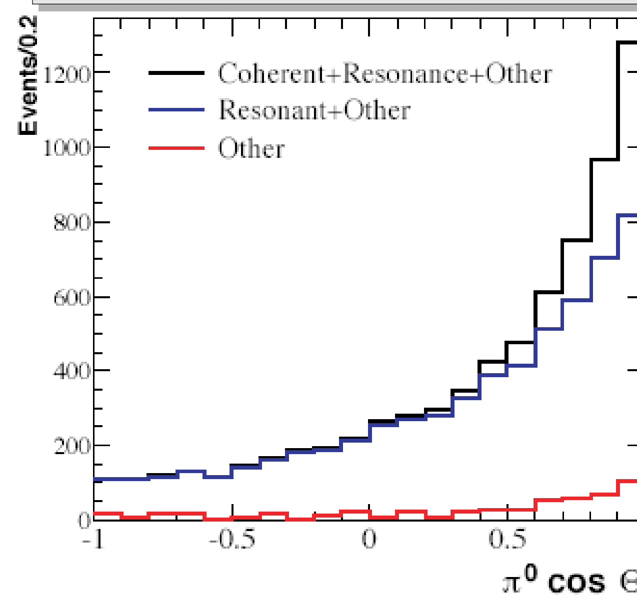
ν_e appearance search is primary purpose, but MiniBooNE can do a lot more...

- ν_μ disappearance
- cross sections, etc.
  - coherent π^0 production (relevant for SuperK sterile ν limits)
  - single K production
  - NC elastic scattering, measurement of Δs
- exotics
  - Q^0 Karmen timing anomaly
    S. Case, S. Koutsoliotas, and M. L. Novak, Phys Rev **D65**, 077701 (2002)
  - neutrino magnetic moment
  - supernova watch

(C. Mauger, NUINT '01)

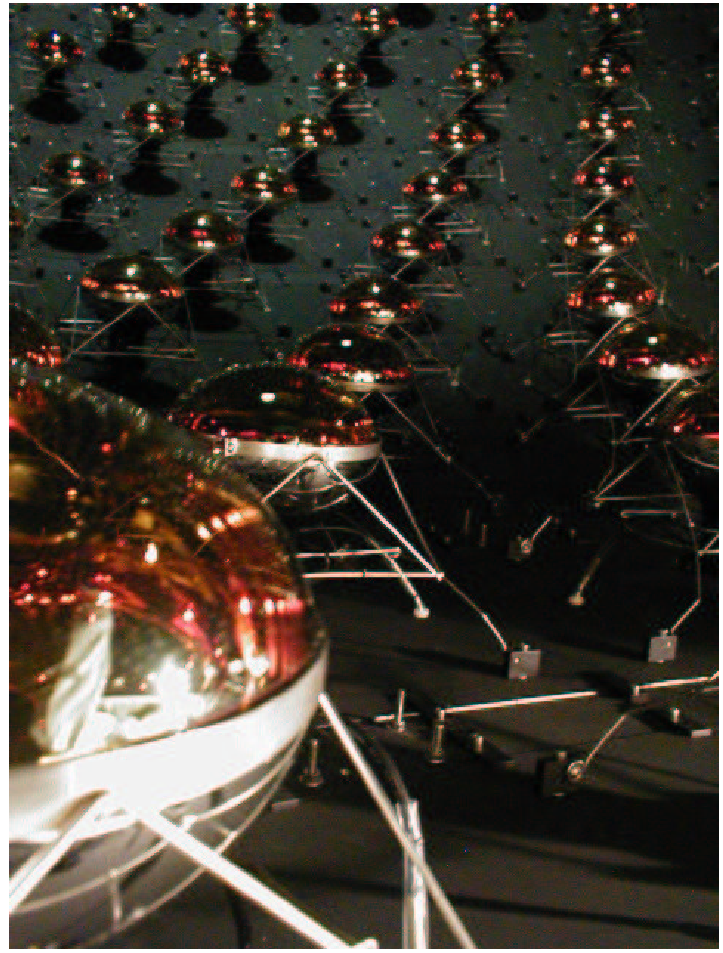


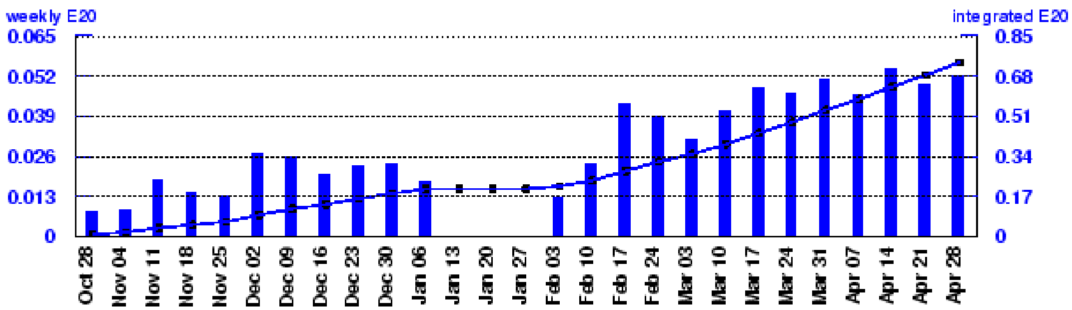
π^0 angular distribution in MiniBooNE (Monte Carlo)



Summary

- steadily taking data; currently at 7% of 10^{21} p.o.t.
- still need more beam
- detector is working well
- appearance results ~2005
- working to get other physics results late this year



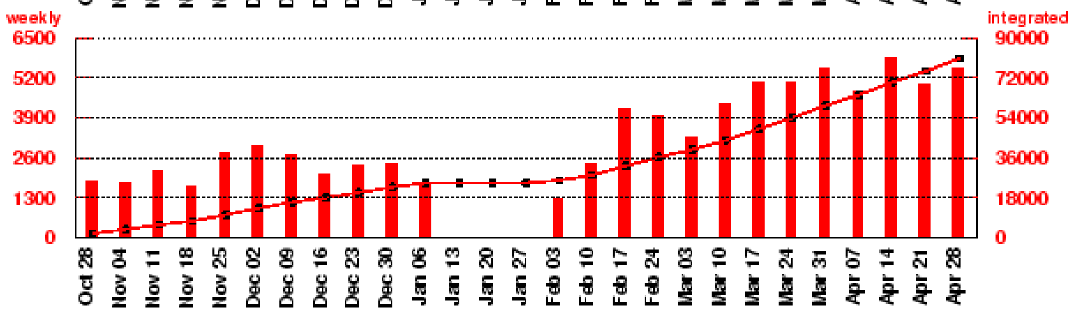


Number of Protons on Target

To date: 0.7371 E20

Largest week: 0.0544 E20

Latest week: 0.0523 E20



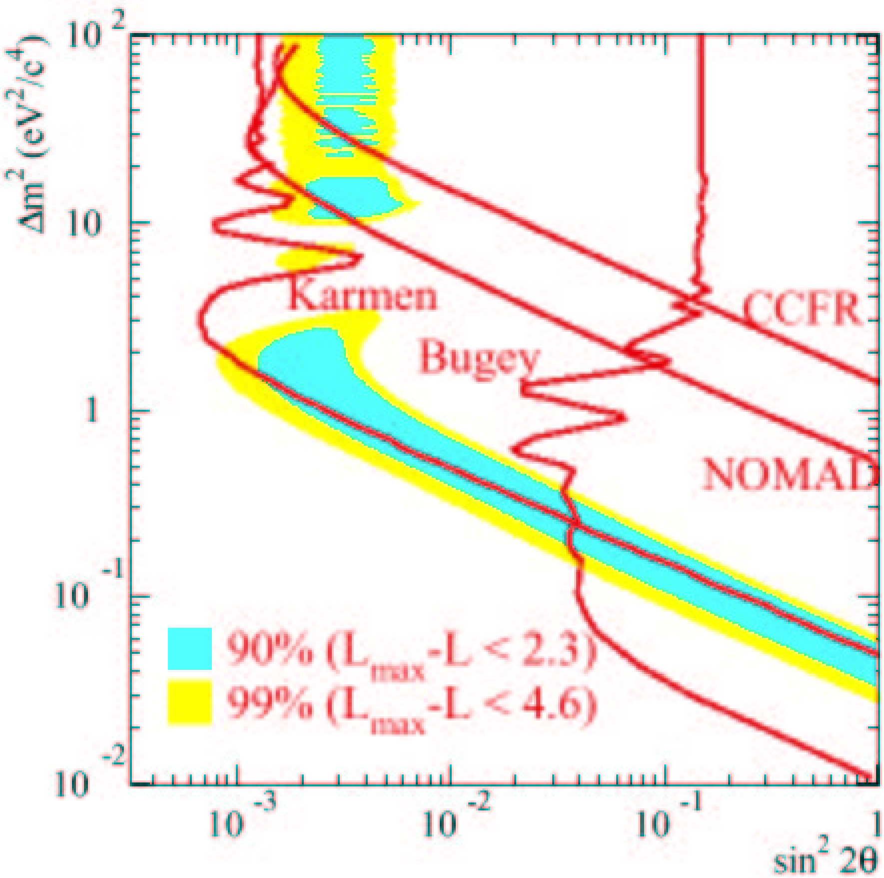
Number of Neutrino Events

To date: 80366

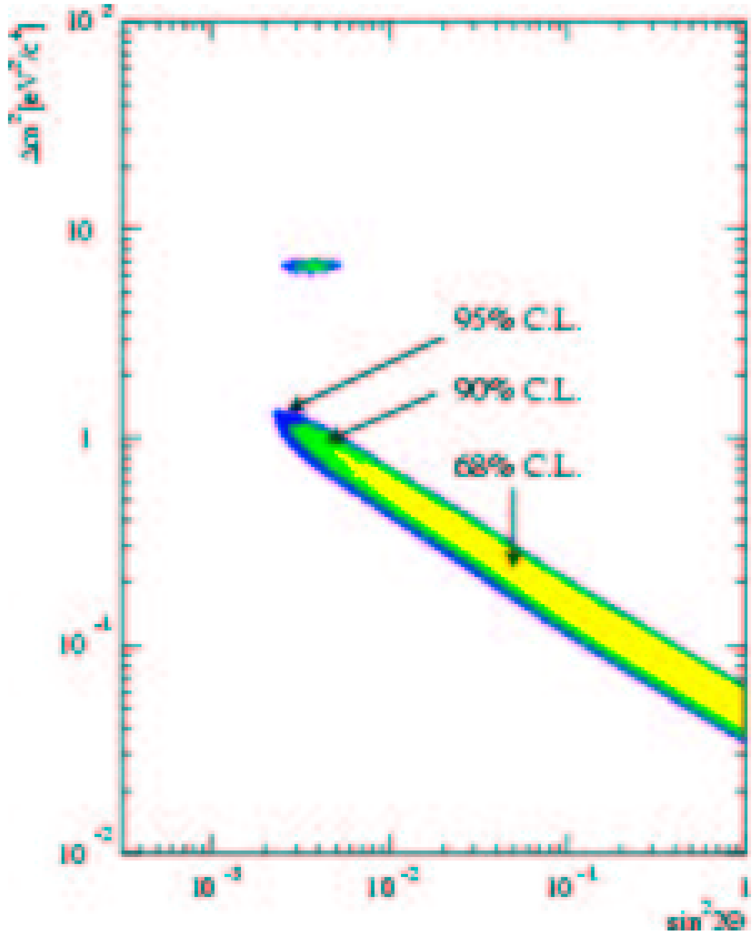
Largest week: 5837

Latest week: 5484

backups...



Regions excluded by other experiments



Joint Karmen/LSND fit

Church, Eitel, Mills, & Steidl
hep-ex/0203023

preliminary $\nu_\mu \rightarrow \nu_x$ sensitivity
at 10% of total p.o.t.